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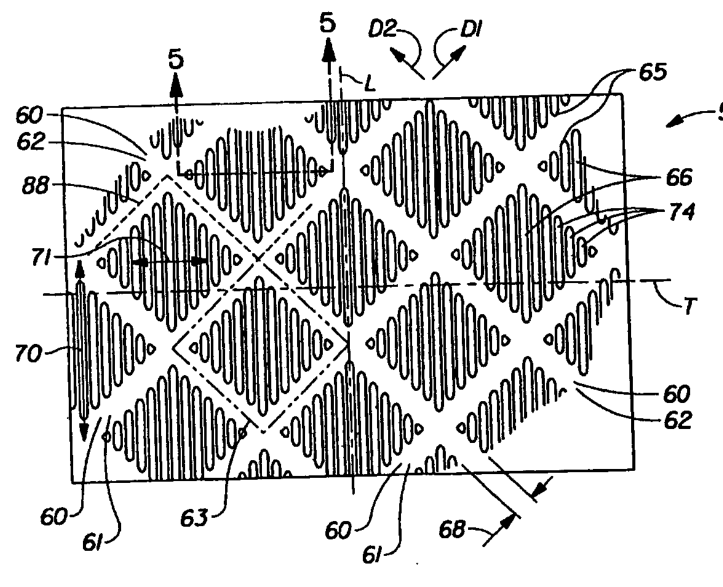
(54) Title: EXTENSIBLE PAPER WEB AND METHOD OF FORMING

(57) Abstract



A paper web of the present invention has a longitudinal centerline (L) and a transverse centerline (T), and comprises a plurality of first regions (60) and a plurality of second regions (66). The first regions (60) form boundaries separating the second regions (66), the first regions (60) being substantially in a plane of the paper web. The second regions (66) comprise a plurality of raised out-of-said-plane rib-like elements (74), the rib-like elements (74) of each second region being disposed parallel to a major rib axis and perpendicular to a minor rib axis. All or most of each first regions have both major rib axis and minor rib axis components. The first and second regions undergo geometric deformation when the web material is subjected to an applied elongation along at least one axis. A method of the present invention comprises the steps of providing a cellulosic substrate; providing a first platen (402) comprising toothed regions (407) and untoothed regions (408); providing a second platen (401) comprising toothed regions, the second platen (401) being aligned with the first platen such that the toothed regions of the first and second platens mesh when operably engaged; and pressing the cellulosic substrate between the first platen and the second platen such that the toothed regions deform said web to form regions of discrete fan-folded rib-like elements. Optionally, the cellulosic substrate can be moistened prior to the pressing step.

EXTENSIBLE PAPER WEB AND METHOD OF FORMING

FIELD OF THE INVENTION

This invention relates to paper webs and methods of making formed paper webs. In particular, this invention relates to disposable absorbent paper webs such as paper towels, wipes, tissues, and toilet tissue and methods of making such webs.

BACKGROUND OF THE INVENTION

Disposable paper products such as paper towels, wipes, facial tissue, and toilet tissue have long been popular, primarily for single or limited use applications. Depending on the intended end use, paper products of this type generally require varying levels of softness, absorbency and strength. In addition to softness, absorbency and strength, the overall look, feel, and performance of disposable paper products is important, particularly in premium paper products.

Two important characteristics that contribute to the overall look, feel, and performance of disposable paper products are bulk and extensibility. Bulk is defined as the ratio of paper thickness to basis weight. Bulk may be increased by increasing the thickness, or caliper, of the paper, without increasing its basis weight, such as by embossing. Extensibility refers to the ability of paper to stretch significantly without tearing. Extensibility is not typically an attribute of uncreped paper webs, particularly tissue paper webs. Foreshortening of paper, such as by creping or wet microcontraction, may increase extensibility, but it also increases basis weight. Tissue paper webs generally have only a few percent elongation to break, due to the relatively inelastic nature of the constituent paper fibers. However, increasing the extensibility, and more preferably the elasticity, of paper webs would significantly enhance the overall look and feel of the paper web.

Increasing bulk without significantly increasing basis weight contributes to the texture and subjective softness of the paper by increasing its compressibility, resulting in a favorable tactile impression to the user. Increasing extensibility contributes to the overall look, feel, and performance of disposable paper products by increasing the

transfer" occurs at a pickup shoe, at which point the web may be molded to the topography of the through air drying belt.

Over time, further improvements became necessary. A significant improvement in through-air-drying belts is the use of a resinous framework on a reinforcing structure. The resinous framework generally has a first surface and a second surface, and deflection conduits extending between these surfaces. The deflection conduits provide areas into which the fibers of the web can be deflected and rearranged. This arrangement allows drying belts to impart continuous patterns, or, patterns in any desired form, rather than only the discrete patterns achievable by the woven belts of the prior art. Examples of such belts and the cellulosic fibrous structures made thereby can be found in U.S. Patents 4,514,345, issued April 30, 1985 to Johnson et al.; 4,528,239, issued July 9, 1985 to Trokhan; 4,529,480, issued July 16, 1985 to Trokhan; and 4,637,859, issued January 20, 1987 to Trokhan. The foregoing four patents are incorporated herein by reference for the purpose of showing preferred constructions of patterned resinous framework and reinforcing type through-air-drying belts, and the products made thereon. Such belts have been used to produce extremely commercially successful products such as Bounty paper towels and Charmin Ultra toilet tissue, both produced and sold by the instant assignee.

Still another improvement to the papermaking process involves a special papermaking apparatus that provides a paper web having multiple basis weight regions. Such a process is described in U.S. Pat. No. 5,245,025, issued September 14, 1993 to Trokhan et al.; U.S. Pat. No. 5,503,715, issued April 2, 1996 to Trokhan et al.; and U.S. Pat. No. 5,534,326, issued July 9, 1996 to Trokhan et al.; the disclosure of each of which is hereby incorporated herein by reference.

All of the above mentioned improvements to conventional papermaking to make bulkier and somewhat more extensible disposable paper products involve significant modifications to existing equipment and machinery. Although the added bulk, with its accompanying characteristics of texture and softness, is desirable, the capital costs associated with modifying a conventional papermaking machine to incorporate the necessary improvements are often prohibitive.

Additionally, it would be desirable to have disposable paper products with increased bulk, texture, and good overall look and feel, together with increased extensibility and elasticity in at least one direction.

Further, it would be desirable to be able to produce paper webs having increased bulk, texture, and good overall look and feel, in a post-papermaking operation that does not require capital expenditures to modify an existing papermaking machine.

SUMMARY OF THE INVENTION

A paper web of the present invention has a longitudinal centerline and a transverse centerline, and comprises a plurality of first regions and a plurality of second regions. The first regions form boundaries separating the second regions, the first regions being substantially in a plane of the paper web. The second regions comprise a plurality of raised out-of-said-plane rib-like elements, the rib-like elements of each second region being disposed parallel to a major rib axis and perpendicular to a minor rib axis. All or most of each first regions have both major rib axis and minor rib axis components. The first and second regions undergo geometric deformation when the web material is subjected to an applied elongation along at least one axis.

A method of the present invention comprises the steps of providing a cellulosic substrate; providing a first platen comprising toothed regions and untoothed regions; providing a second platen comprising toothed regions, the second platen being aligned with the first platen such that the toothed regions of the first and second platens mesh when operably engaged; and pressing the cellulosic substrate between the first platen and the second platen such that the toothed regions deform said web to form regions of discrete fan-folded rib-like elements. Optionally, the cellulosic substrate can be moistened prior to the pressing step.

BRIEF DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims particularly pointing out and distinctly claiming the present invention, it is believed that the present invention will be

by various air-laying processes, which may or may not include the introduction of water to the air-laid web. Air-laid paper webs may be bonded by methods known in the art, including by use of synthetic fibers, latex, etc.

As used herein, "fibers" refers to fibers suitable for use in forming paper webs of the present invention, including mineral, vegetable, animal, and synthetic fibers. Preferred fibers are vegetable fibers including wood and non-wood fibers. Most preferred in the context of the present invention are wood fibers, such as softwoods and hardwoods typically used for cellulosic paper, such as tissue paper. In general, suitable wood fibers are elongated, tapering, thick-walled plant cells that impart flexibility and tensile strength to paper.

Paper fibers preferred for making tissue paper are generally inelastic. By inelastic is meant that the fibers are not considered to be elastomeric in nature. Further, as a consequence of the nature of fiber-to-fiber bonding in the finished paper web, tissue paper of the type generally useful for bath tissue, towel or wipe applications, is not generally considered to be elastomeric in nature. Although foreshortening provides for some extensibility, when formed on typical papermaking machines uncreped cellulosic paper products tend to be rather inelastic, and substantially inextensible due to the high density of fiber-to-fiber bonding. Rather than extend, the fiber-to-fiber bonds tend to rupture, resulting in tearing.

Therefore, tissue paper webs formed on conventional paper making machines are not only substantially inelastic, but they also do not exhibit appreciable amounts of non-elastic extensibility. In other words, as opposed to web and film materials comprising thermoplastic materials, paper webs generally are not considered elastomeric or extensible in nature. Paper webs do not tend to have the "molecular-level" deformation associated with plastically-deformable materials. However, as disclosed below, the paper of the present invention is unexpectedly highly extensible, and even elastomeric to a certain degree. This surprising extensibility and elasticity are imparted to a base paper web, without regard to the method of manufacture, i.e., conventional or non-conventional drying.

The strainable network includes a plurality of first regions **60** and a plurality of second regions **66**. Paper web **52** also includes transitional regions **65** which are located at the interface between the first regions **60** and the second regions **66**. The transitional regions **65** will exhibit complex combinations of the behavior of both the first region and the second region. It is recognized that every embodiment of the present invention will have transitional regions, however, the present invention is largely defined by the behavior of the web material in distinctive regions (e.g., first regions **60** and second regions **66**). Therefore, the ensuing description of the present invention will be concerned with the behavior of the web material in the first regions **60** and the second regions **66** only since it is not significantly dependent upon the complex behavior of the web material in the transitional regions **65**.

While first regions **60** are described herein as a "plurality" of first regions **60**, it is appreciated that in some embodiments, such as the preferred embodiment of FIG. 1, the plurality of first regions **60** may form a single, interconnected, continuous network "region". As used herein, therefore, the term "plurality of first regions **60**" encompasses interconnected first regions which form a single, continuous network region. Although interconnected into a single, continuous network region, first regions **60** can still be considered as discrete, interconnected and intersecting regions, for example regions **61** and **62**, as described below.

Paper web **52** has a first surface, (facing the viewer in FIGs. 1 and 2), and an opposing second surface (not shown). In the preferred embodiment shown in FIG. 1, the strainable network includes a plurality of first regions **60** and a plurality of second regions **66**. One set of first regions **60**, indicated generally as **61**, are preferably linear and extend in a first direction, denoted generally as **D1**. The remaining first regions **60**, indicated generally as **62**, are preferably linear and extend in a second direction, denoted generally as **D2**, which is substantially perpendicular to the first direction. While it is preferred that the first direction be perpendicular to the second direction, other angular relationships between the first direction and the second direction may be suitable so long as the first regions **61** and **62** intersect one another. Preferably, the angle between the first and second directions ranges from about 45° to about 135°, with 90° being the most

As shown in FIGs. 1 and 2, the paper web **52** has been "formed" by methods disclosed below such that the paper web **52** exhibits extendible or elastomeric properties along an axis, which in the case of the illustrated embodiments is substantially parallel to the transverse axis of the paper web, when subjected to an applied axial elongation in a direction substantially parallel to the transverse axis. As used herein, the term "formed" refers to the creation of a desired structure or geometry upon a paper web that will substantially retain the desired structure or geometry when it is not subjected to any externally applied elongation or forces.

First regions **60** are substantially macroscopically monoplanar, that is, substantially unmodified by subsequent processing such that they experience little or no out of plane deformation. That is, the material within the first regions **60** is in substantially the same condition before and after the formation step undergone by web **52**. The second regions **66** include a plurality of raised rib-like elements **74**. The rib-like elements **74** may be embossed, debossed or a combination thereof to form what can generally be described as "fan-folded" structures. Each fan-folded structure of rib-like elements **74** has a first or major rib axis **70** which is substantially parallel to the longitudinal axis of the web **52** and a second or minor rib axis **71** which is substantially parallel to the transverse axis of the web **52**. For each rib-like element **74**, major rib axis **70** is substantially perpendicular to minor rib axis **71**. The rib-like elements **74** can be contiguous, having no unformed areas between them.

The major rib axis **70** and minor rib axis **71** of the raised rib-like elements may be oriented relative to the plane of the web in ways other than shown in FIGs. 1 or 3, such as by orienting the major rib axis **70** substantially parallel with the transverse axis of the web. Also, it is currently preferred that the major axes **70** of each rib-like element **74** be aligned parallel to one another, but many benefits of the present invention, including increased bulk, can be realized even if they are not.

As web **52** is subjected to an applied axial strain, **D**, indicated by arrows **80**, shown in FIG. 3, the rib-like elements **74** in the second regions **66** experience geometric deformation, or unfolding, and offer minimal resistance to the applied elongation. In addition, the shape of the first regions **60** changes as a result of the applied axial strain,

major rib axes **70**, as shown in FIG. 4, but having the major rib axes **70** in parallel alignment with transverse axis T, which, in turn, can correspond to the cross machine direction during web processing.

Without being bound by theory, it is believed that the extensible, or elastic, nature of a paper web of the present invention is due to the ability of the fan-folded structure of second regions **66** to "unfold" in a three-dimensional geometric manner along the rib-like elements. At the same time, the first regions **60** contract in a direction generally perpendicular to the applied loading, in a two-dimensional, geometric manner generally in the plane of the paper web, as shown in FIG. 3. The contraction of first regions **60** and resulting shape change of second regions **66** can be considered analogous to a two dimensional Poisson effect. For example, as best described with reference to FIG. 1, as the web is extended in a direction generally parallel to the transverse centerline **T**, the shape of second regions **60** change as depicted in FIG. 2, with one dimension increasing, and another dimension decreasing. As discussed above, the simultaneous unfolding of second regions **66**, and contraction of first regions **60**, is provided for by avoiding substantial parallel alignment of the major or minor axes **70** or **71**, with either the first or second directions, **D1** or **D2** of first regions **60**.

One additional very beneficial attribute of a paper web of the present invention is its ability to increase in bulk in response to extension in at least one direction. Without wishing to be bound by theory, this behavior is now described in terms of discrete modes of geometric deformation, with reference to FIGS. 5 and 6. FIG. 5 shows cross-section 5-5 of an unstretched portion of web **52**, as shown in FIG. 1. Second region **66** is shown with representative rib-like elements **74** as initially formed by the method of the present invention. At initial formation, rib-like elements give the paper web an initial caliper **C1**. When subjected to an applied axial elongation, **D**, indicated by arrows **80** in FIGS. 2 and 6, the rib-like elements **74** in the second regions **66** experience a first mode of geometric deformation, that is, unfolding of the rib-like elements in accordion-like fashion. As the first mode geometric deformation occurs, the shape of the second regions **66** simultaneously changes as a result of a second mode of geometric deformation, that is, movement of the reticulated structure formed by the first regions **60**, such as intersecting

positioned between toothed regions **407** of plate **402**, (which comprise teeth **404**), and teeth **403** of plate **401** are incrementally formed creating rib-like elements **74** in the second regions **66** of paper web **52**.

While FIG. 7 shows plates suitable for use in producing paper having a pattern of first regions **60** as shown in FIG. 1, one skilled in the art can easily envision similar plates for producing other patterns, such as the patterns shown in FIGs. 2 and 4. It is believed that the paper of the present invention is pattern-independent, i.e., as long as first regions **60** form a pattern of "reticulated structures", and second regions **66** have raised rib-like members, such that first and second regions may undergo geometric deformation as described above, the pattern is within the scope of the present invention. Such patterns allow the disclosed modes of geometric deformation to occur, which in turn allow the paper to exhibit extensibility, elasticity and increased caliper upon tensioning.

Likewise, while FIG. 7 shows one plate with toothed regions (plate **401**) and one plate with grooved, i.e., untoothed, regions (plate **402**), one skilled in the art can easily envision both plates having toothed regions **407** and grooved regions **408**. In this configuration, it may be advantageous to use identical patterned plates which intermesh with the patterns in registry, or in an offset position, with the patterns in a regular or random offset pattern. It may be advantageous to use plates, both having toothed and untoothed regions, in which one plate has untoothed regions forming a first pattern, and the other plate has untoothed regions forming a second, different, pattern. These and other variations in plate design and configuration are meant to be exemplary, but not limiting, of preferred and contemplated embodiments of the present invention.

FIG. 8 shows a partial cross-section of meshing teeth **403** and **404**. The depth, spacing, and frequency of rib-like elements can be varied to control the resulting increase in caliper, as well as the available stretch of a web of the present invention. In particular, the frequency, spacing, and depth of rib-like elements **74** determines the surface-pathlength of the second region. As used herein, "surface-pathlength" refers to a measurement along the topographic surface of the region in question in a direction substantially parallel to an axis, as disclosed in commonly assigned U.S. Pat. No.

accomplished. Once web **52** is formed, it may be guided by suitable means **605** to further converting processes, such as take-up roll **620**. Further method variations are contemplated, including methods and variations fully described in U. S. Pat. No. 5,518,801 issued to Chappell, et al. on May 21, 1996 which is hereby incorporated herein by reference.

While FIG. 9 shows one roll with toothed regions (roll **501**) and one plate with grooved, i.e., untoothed, regions (roll **502**), one skilled in the art can easily envision both rolls having toothed regions **507** and grooved regions **508**. In this configuration, it may be advantageous to use identical patterned rolls which intermesh with the patterns in registry, or in an offset position, with the patterns in a regular or random offset pattern. It may be advantageous to use rolls, both having toothed and untoothed regions, in which one roll has untoothed regions forming a first pattern, and the other roll has untoothed regions forming a second, different, pattern. Similarly, it may be advantageous to use rolls having differing diameters, with the same or different patterns formed by the grooved regions **508**. These and other variations in roll design and configuration are meant to be exemplary, but not limiting, of preferred and contemplated embodiments of the present invention.

In an alternative embodiment, the method of the present invention includes the application of a wetting agent to web **50** prior to forming in press rolls **500**. A preferred wetting agent is water, but other wetting agents, including, for example, wet strength chemicals, softening chemicals, may be added. While the addition of wetting agents does not significantly affect caliper increase or extensibility properties, it does appear to minimize the loss of tensile strength experienced after processing. Without being bound by theory, it appears that the addition of a wetting agent, e.g., water, preserves a certain amount of tensile strength due to plasticization of the cellulosic fiber structure. The addition of water plasticizes the cellulosic structure to allow it to be more readily formed by the method of the present invention without as much fiber breakage as would be experienced under dry conditions. This plasticization is probably due to the reduction of hydrogen boding within the cellulosic structure, and relies on fiber swell to plasticize and allow the fibers to be more flexible. Wet strength additives (added during web

66 of each may be positioned such that they are in registry in the laminate structure. Alternatively, it may be beneficial to place the second regions of each ply such that they are out of registry when laminated. Similarly, it may be beneficial to form a multiple ply laminate using a first pattern on one web, and a second, different pattern on the another web.

In the event that extensibility of the paper web is not desired, a multiple ply laminate may be made that has essentially double the bulk of each base web without the extensibility of either base web. This may be accomplished by laminating at least two webs of the present invention, each having major rib axes **70** of second regions **66** being generally perpendicular to the major rib axes **70** of the second regions **66** of the other ply. For example, with reference to FIG. 1, one web having second regions **66** with a major rib axis **70** generally parallel to longitudinal centerline "L" may be laminated with a second web having second regions **66** with a major rib axis **70** generally perpendicular to longitudinal centerline "L". Since paper web **52** can be made to exhibit relatively little extensibility in the direction generally parallel to first axes **70**, a laminate made in the fashion may exhibit relatively little extension in either direction.

Examples

The following are examples of specific embodiments of the present invention. Data for caliper, elongation, and tensile strength were obtained by the test methods disclosed in the Test Methods section below.

Example 1

A paper web of the invention was made using intermeshing plates, similar to those depicted in FIG. 7. The intermeshing plates were made by casting an aluminum filled epoxy material on a machined metal mold to produce two intermeshing plates approximately 5 inches wide, 12 inches long, and 0.75 inches thick. The teeth of the intermeshing plates were essentially triangle-shaped, i.e., tapered, measuring about 0.030 inches at the base and tapering to a vertex having a radius of approximately 0.008 inches. The height of each tooth was 0.060 inches and they were set on a pitch of 0.030 inches.

A paper web of the invention was made by the process depicted in FIG. 10. The rollers of press rolls **500** were made by machining grooves into two 10-inch long, six-inch diameter steel rolls, corresponding to rollers **501** and **502** shown in FIG. 9. The machined grooves defined teeth corresponding to teeth **503** and **504** as shown in FIG. 9. The teeth were substantially triangle-shaped measuring about 0.030 inches at the base and tapering to a vertex having a radius of approximately 0.004 to 0.008 inches. The height of each tooth was 0.060 inches and they were set on a pitch of 0.030 inches. A series of grooves corresponding to grooved regions **508** of FIG. 9 were machined on of the rollers corresponding to roller **502** of FIG. 9. The grooves measured 0.040 inches in width with parallel grooves being on 0.275 inch center to center spacing. The two rollers were set in intermeshing relationship to form toothed press rolls, corresponding to press rolls **500** as shown in FIG. 10.

A single ply paper web of Northern Softwood Kraft fibers having a basis weight of 20 lbs. per 3000 sq. ft. was made on conventional papermaking equipment and provided on a roll, corresponding to roll **610** of FIG. 10. The paper was fed into the press rolls at a rate of 45 ft per min with the press rolls set at various levels of engagement. The toothed and untoothed regions of the press rolls were configured such that the machine direction of the paper web was parallel to the major rib axis of the rib-like elements of the formed paper. Water, if used, was applied with a Spray Systems Co. of Wheaton, IL nozzle, in particular nozzle number 2850/73320, prior to forming in the press rolls.

Table 1 below shows how the caliper and cross direction stretch of the base paper web changed as a result of various levels of engagement and application of water to the web. Additionally, the change in machine direction tensile strength is shown to illustrate further beneficial results of adding water to the web prior to forming. As can be seen from Table 1, caliper and machine direction stretch are successfully increased with increasing engagement. Of special note is the comparison of the results of an engagement of 0.020 inches with, and without, application of water. Even though machine direction tensile properties decline with increasing engagement, the application of water substantially improves the machine direction tensile properties for a particular engagement.

of the deformed region is represented. There will be cases (due to variations in either the size of the deformed portion or the relative geometries of regions 1 and 2) in which it will be necessary to cut either larger or smaller samples than is suggested herein. In this case, it is very important to note (along with any data reported) the size of the sample, which area of the deformed region it was taken from and preferably include a schematic of the representative area used for the sample. Three samples of a given material are tested.

The grips of the Thwing-Albert tensile tester consist of air actuated grips designed to concentrate the entire gripping force along a single line perpendicular to the direction of testing stress. The distance between the lines of gripping force should be 4" as measured by a steel rule held beside the grips. This distance will be referred to from hereon as the "gauge length". The sample is mounted in the grips with its long axis perpendicular to the direction of applied percent elongation. The crosshead speed is set to 4 in/min. The crosshead elongates the sample until the sample breaks at which point the crosshead stops and returns to its original position (0 % elongation). The percent stretch is percent elongation at which the maximum load is achieved prior to failure of the paper sample. The average percent stretch for three samples is recorded in Table 1.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modification can be made without departing from the spirit and scope of the present invention. Additionally, while an entire web of the present invention may include a strainable network of first and second regions, the present invention may also be practiced by providing only specific portions of the paper web with a strainable network comprised of first and second regions. The foregoing is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of the present invention.

5. The paper web of any of Claims 1-4, wherein said rib-like elements are capable of undergoing a third mode of geometric deformation, said third mode of geometric deformation being an out-of-said-plane extension of said second region when said web material is subjected to an applied elongation along at least one said axis.

6. A multiple ply paper web, having at least one ply having a longitudinal centerline and a transverse centerline, a plurality of first regions and a plurality of second regions, said first regions forming boundaries separating said second regions, said paper web characterized by said first regions being substantially in a plane of said paper web and said second regions comprising a plurality of raised out-of-said-plane rib-like elements, said rib-like elements of each said second region being disposed parallel to a major rib axis and perpendicular to a minor rib axis, with all or most of each said first regions having both major rib axis and minor rib axis components; said first and second regions undergoing geometric deformation when said web material is subjected to an applied elongation along at least one said axis.

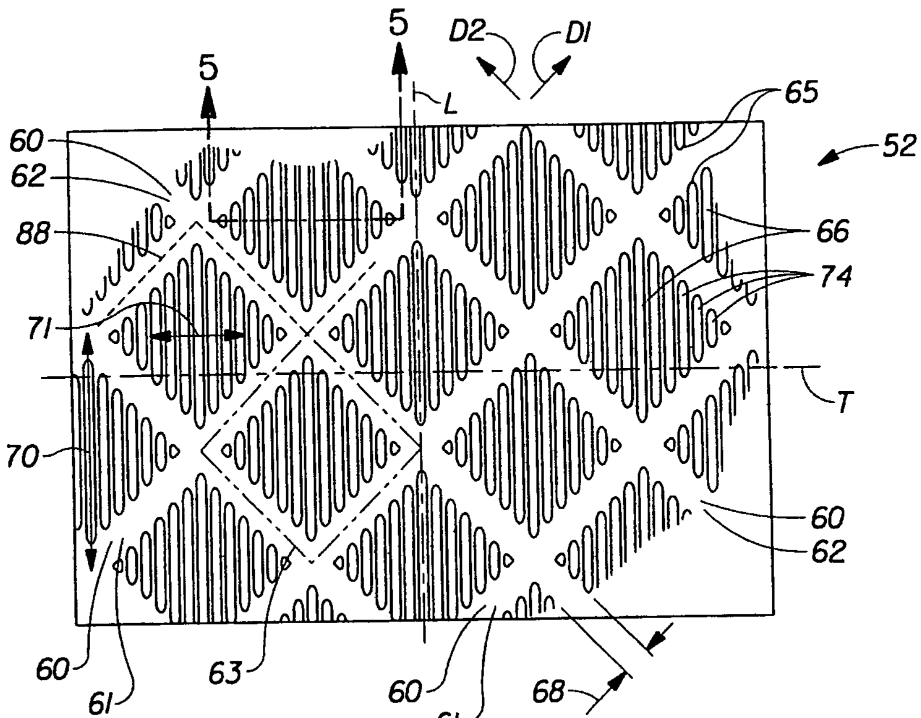
7. The multiple ply paper web of Claim 6, wherein said first regions of at least one ply form a continuous network, such that said first region forms boundaries completely surrounding said second regions.

8. A method of making a cellulosic web, said method characterized by the steps of:

(a) providing a cellulosic substrate;

(b) providing a first platen comprising toothed regions and untoothed regions;

(c) providing a second platen comprising toothed regions, said second platen being aligned with said first platen such that said toothed regions of said first and second platens mesh when operably engaged;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5
D2
D1
L
65
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88
66
74
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T
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61
68

Fig. 1

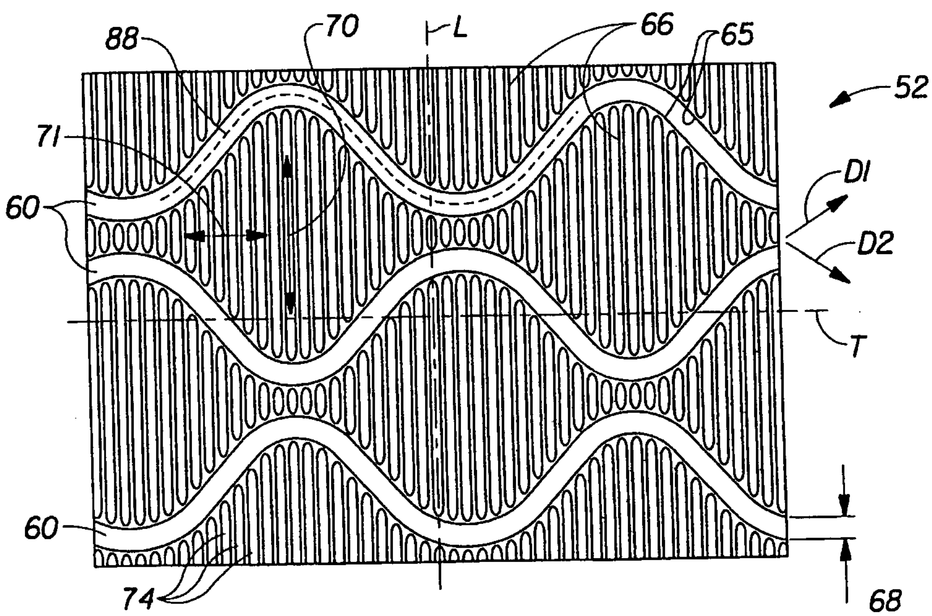
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Fig. 2

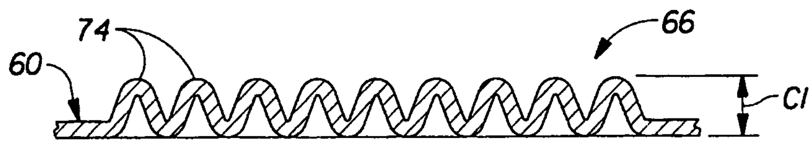

Fig. 5

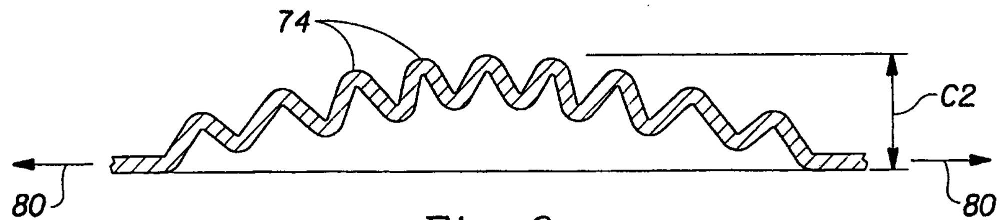

Fig. 6

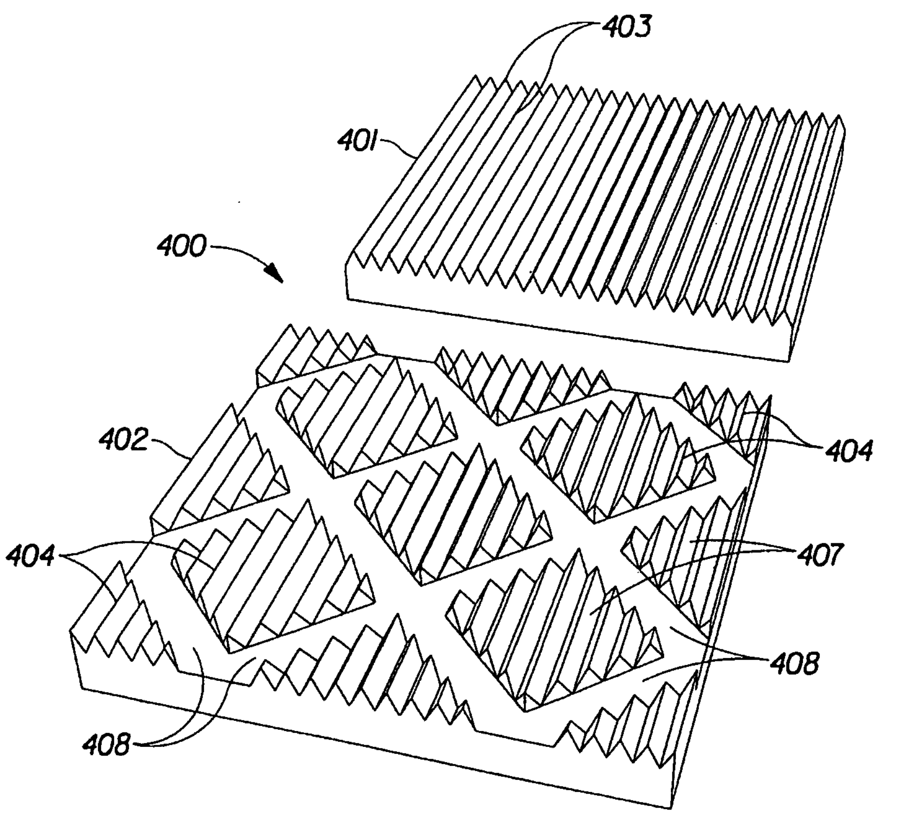

Fig. 7

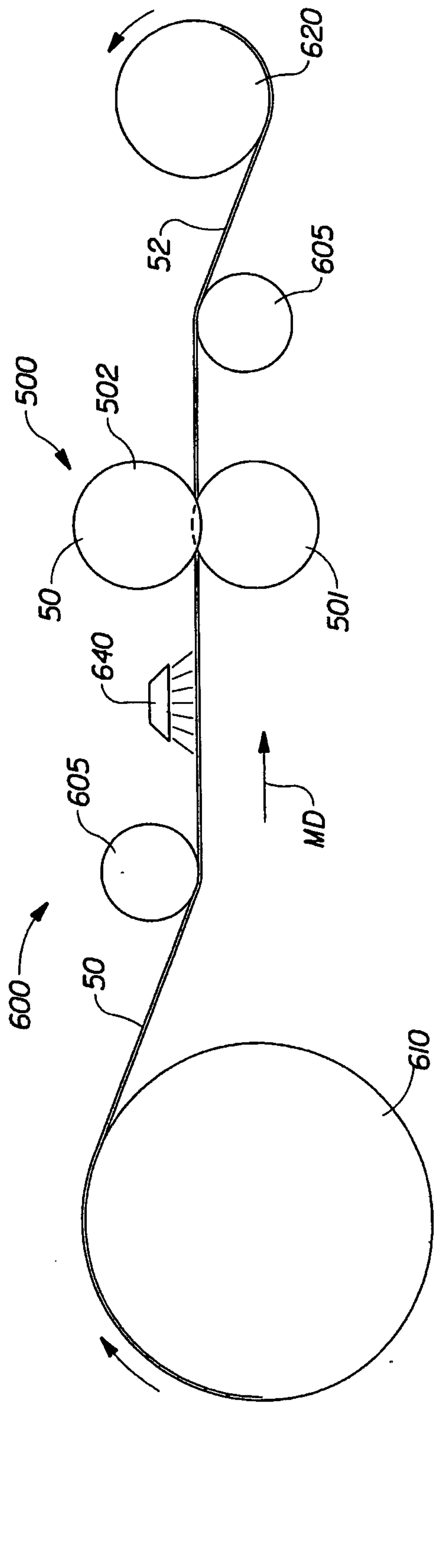

Fig. 10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB 99/00631

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